Claims

1. An ophthalmic data measuring apparatus comprising:

a first light source part to emit a light flux of a first wavelength;

a first illuminating optical system for performing illumination to condense the light flux from the first light source part on a vicinity of a retina of an eye to be examined;

a first light receiving optical system for receiving a part of the light flux reflected by and returning from the retina of the eye to be examined through a first conversion member to convert it into at least substantially 17 beams;

a first light receiving part for receiving the received light flux of the first light receiving optical system; and

a calculation section to perform Zernike analysis based on an inclination angle of the light flux obtained by the first light receiving part, to obtain an optical characteristic of the eye to be examined, and (1) to estimate one of or two or more of a visual acuity, the optical characteristic and a sensitivity of the eye to be examined under an observation condition corresponding to an environment of the eye to be examined, or (2) to calculate appropriate correction data suitable for the eye to be examined,

wherein the calculation section comprises:

first means for obtaining measurement data indicating a refractive power distribution of the eye to be examined and pupil data including a value of a pupil diameter of the eye to be examined or a pupil diameter image and for obtaining lower order aberrations and higher order aberrations based on an observation condition parameter including the measurement data

and the pupil data;

second means for calculating an evaluation parameter indicating quality of visibility by the eye to be examined based on the observation condition parameter and/or the obtained lower order aberrations and the higher order aberrations; and

third means for, in accordance with the calculated evaluation parameter, (1) estimating one of or two or more of the visual acuity, the optical characteristic and the sensitivity, of the eye to be examined under the observation condition corresponding to the environment of a subjective eye or (2) calculating the appropriate correction data suitable for the eye to be examined by changing the lower order aberration.

2. The ophthalmic data measuring apparatus according to claim 1, wherein

the pupil data is data corresponding to the observation condition in accordance with the environment of the subjective eye and/or

the second means simulates the visibility of an image by the eye to be examined and calculates the evaluation parameter indicating the quality of the visibility.

3. The ophthalmic data measuring apparatus according to claim 1, wherein the first means is constructed to cause

the calculation section to receive the measurement data indicating the refractive power distribution of the eye to be examined, and the pupil data including the pupil image at a time of measurement or under a correction environment in which the correction data is obtained, to calculate a pupil diameter under the observation condition or the correction environment based

on the received pupil data, and to obtain the lower order aberrations and the higher order aberrations based on the received measurement data and the calculated pupil diameter.

4. The ophthalmic data measuring apparatus according to claim 1, wherein the first means comprises:

means by which the calculation section receives the measurement data indicating the refractive power distribution of the eye to be examined and the pupil data including the pupil image at the time of measurement or under the correction environment;

means by which the calculation section detects points on a pupil edge based on the received pupil data;

means by which the calculation section calculates a focal point and a major axis and/or a minor axis of an ellipse fitted to the detected points;

means by which the calculation section calculates the pupil diameter of the eye to be examined based on the major axis and/or the minor axis of the ellipse; and

means by which the calculation section obtains the lower order aberrations and the higher order aberrations based on the received measurement data and the calculated pupil diameter.

5. The ophthalmic data measuring apparatus according to claim 1, further comprising:

a second light source to emit a light flux of a second wavelength;

a second illuminating optical system to illuminate a vicinity of a cornea of the eye to be examined with a predetermined pattern and by the second illumination light flux

from the second light source;

a second light receiving optical system to receive the second illumination light flux reflected by and returning from the vicinity of the cornea of the eye to be examined;

a second light receiving part to receive the received light flux of the second light receiving optical system; and

a pupil data formation part to form pupil data of the eye to be examined from output of the second light receiving part,

wherein the calculation section is constructed to obtain the pupil data by the pupil data formation section.

6. The ophthalmic data measuring apparatus according to claim 1, further comprising an anterior ocular segment illuminating part constructed to be capable of illuminating an anterior ocular segment of the eye to be examined at desired brightness,

wherein the calculation section is constructed to adjust the anterior ocular segment illuminating part to produce brightness corresponding to a predetermined observation condition or correction environment, and to estimate the visual acuity of the eye to be examined and/or the sensitivity based on an output signal of the first light receiving part in the illumination state and the pupil data, or to obtain the appropriate correction data suitable for the eye to be examined.

7. The ophthalmic data measuring apparatus according to claim 6, wherein the anterior ocular segment illuminating part is constructed to perform measurement by sequentially changing the illumination state from a dark one to a bright one in a case where plural illumination states are formed.

8. The ophthalmic data measuring apparatus according to claim 1, wherein the second means comprises:

means by which the calculation section simulates the visibility of an index for eye examination by the eye to be examined before or after correction to form index image data;

means by which the calculation section compares the index image data with pattern data of the index for eye examination by patterning matching; and

means by which the calculation section calculates the evaluation parameter based on a comparison result by the pattern matching.

9. The ophthalmic data measuring apparatus according to claim 1, wherein the calculation section is constructed to estimate a high contrast visual acuity and/or a low contrast visual acuity of the eye to be examined by using a high contrast index for eye examination and/or a low contrast index for eye examination.

10. The ophthalmic data measuring apparatus according to claim 1, wherein with respect to the third means, the calculation section judges whether the evaluation parameter indicating visibility of an index for eye examination satisfies a previously specified reference, and estimates the visual acuity in accordance with a size of the index for eye examination corresponding to the evaluation parameter satisfying the reference.

11. The ophthalmic data measuring apparatus according

to claim 10, wherein the calculation section further comprises:

means for obtaining data of an MTF (Modulation Transfer Function) indicating a transfer characteristic of the eye to be examined based on the lower order aberrations and the higher order aberrations; and

means for estimating a contrast sensitivity based on the obtained data of the MTF.

12. The ophthalmic data measuring apparatus according to claim 1, wherein with respect to the second means,

the calculation section obtains data of an MTF (Modulation Transfer Function) indicating a transfer characteristic of the eye to be examined based on the lower order aberrations and the higher order aberrations; and

with respect to the third means, the calculation section estimates a contrast sensitivity based on the obtained data of the MTF.

13. The ophthalmic data measuring apparatus according to claim 1, wherein the calculation section further comprises means for obtaining a pupil center position under the observation condition based on the received pupil data and for calculating a shift amount of the pupil center position to shift an analysis center.

14. The ophthalmic data measuring apparatus according to claim 1, wherein the calculation section further comprises means for storing one of or two or more of the visual acuity, the sensitivity, the correction data, and a simulation result into a memory or displaying them on a display section.

15. The ophthalmic data measuring apparatus according to claim 1, wherein the third means is constructed to estimate, as the optical characteristic, an MTF (Modulation Transfer Function) of the eye to be examined, and a point spread function (PSF).

16. The ophthalmic data measuring apparatus according to claim 1, wherein the calculation section further comprises

means for obtaining the appropriate correction data suitable for the eye to be examined by changing the lower order aberration corresponding to defocus in accordance with the evaluation parameter calculated by the second means and for simulating the visibility of an image by the eye to be examined at a time of correction based on the correction data to further calculate an evaluation parameter,

and estimates the visual acuity and/or the sensitivity at the time of correction.

17. The ophthalmic data measuring apparatus according to claim 1, wherein the calculation section further comprises

means for obtaining appropriate correction data suitable for the eye to be examined by changing the lower order aberration corresponding to an astigmatic component in accordance with the evaluation parameter calculated by the second means and for simulating the visibility of an image by the eye to be examined at a time of correction based on the correction data to further calculate an evaluation parameter,

and estimates the visual acuity and/or the sensitivity at the time of correction.

18. The ophthalmic data measuring apparatus according to claim 1, wherein the calculation section further comprises

fourth means for simulating a Landolt's ring based on the calculated correction data or a luminance distribution image of an arbitrary image, and storing the correction data and/or a simulation result into a memory or displaying it on a display section.

19. The ophthalmic data measuring apparatus according to claim 1, wherein with respect to the third means, in a case where a higher order spherical aberration or an unsymmetrical higher order coma aberration has a predetermined value or more, the calculation section changes the lower order aberration corresponding to defocus based on the evaluation parameter and obtains the appropriate correction data suitable for the eye to be examined.

20. The ophthalmic data measuring apparatus according to claim 1, wherein with respect to the third means, in a case where a higher order astigmatic aberration has a predetermined value or more, the calculation section changes the lower order aberration corresponding to an astigmatic component based on the evaluation parameter and obtains the appropriate correction data suitable for the eye to be examined.

21. The ophthalmic data measuring apparatus according to claim 1, wherein

with respect to the second means, the calculation section calculates a Strehl ratio as the evaluation parameter based on

the obtained lower order aberrations and the higher order aberrations, and

with respect to the third means, the calculation section changes a predetermined lower order aberration to increase the Strehl ratio and calculates the appropriate correction data suitable for the eye to be examined.

22. The ophthalmic data measuring apparatus according to claim 1, wherein

with respect to the second means, the calculation section calculates a phase shift as the evaluation parameter based on the obtained lower order aberrations and the higher order aberrations, and

with respect to the third means, the calculation section changes the lower order aberration to decrease a phase shift and calculates the appropriate correction data suitable for the eye to be examined.

23. The ophthalmic data measuring apparatus according to claim 1, wherein the second means comprises:

means by which the calculation section forms data of an MTF (Modulation Transfer Function) indicating a transfer characteristic of the eye to be examined after correction based on the lower order aberrations and the higher order aberrations, and

means by which the calculation section calculates the evaluation parameter based on the formed data of the MTF.

24. The ophthalmic data measuring apparatus according to claim 1, wherein

with respect to the second means, the calculation section forms, as the evaluation parameter, a relational expression between a Strehl ratio and a phase shift based on the lower order aberrations and the higher order aberrations, and

with respect to the third means, the calculation section changes the lower order aberration to obtain a condition under which the Strehl ratio becomes maximum and the phase shift becomes substantially zero, and makes the lower order aberration at that time the appropriate correction data.

25. An ophthalmic data measurement program for causing a computer to execute:

a first step at which a calculation section obtains measurement data indicating a refractive power distribution of an eye to be examined and pupil data including a value of a pupil diameter of the eye to be examined or a pupil diameter image, and obtains lower order aberrations and higher order aberrations based on an observation condition parameter including the measurement data and the pupil data;

a second step at which the calculation section calculates an evaluation parameter indicating quality of visibility by the eye to be examined based on the observation condition parameter and/or the obtain lower order aberrations and the higher order aberrations; and

a third step at which in accordance with the calculated evaluation parameter, the calculation section estimates one of or two or more of a visual acuity, an optical characteristic and a sensitivity of the eye to be examined under an observation condition corresponding to an environment of a subjective eye, or calculates appropriate correction data suitable for the eye

to be examined by changing the lower order aberration

26. An ophthalmic data measurement program for causing a computer to execute:

a first step at which a calculation section receives measurement data indicating a refractive power distribution of an eye to be examined, and obtains lower order aberrations and higher order aberrations based on the measurement data;

a second step at which the calculation section calculates an evaluation parameter indicating quality of visibility by the eye to be examined based on the obtained lower order aberrations and the higher order aberrations; and

a third step at which the calculation section calculates appropriate correction data suitable for the eye to be examined by changing the lower order aberration in accordance with the calculated evaluation parameter.

27. An eye characteristic measuring apparatus comprising:

a first light source part to emit a light flux of a first wavelength;

a first illuminating optical system for performing illumination to condense the light flux from the first light source part on a vicinity of a retina of an eye to be examined;

a first light receiving optical system for receiving a part of the light flux reflected by and returning from the retina of the eye to be examined through a first conversion member to convert it into at least substantially 17 beams;

a first light receiving part for receiving the received light flux of the first light receiving optical system; and

a calculation section for receiving pupil data including a pupil image of the eye to be examined in a measurement environment, calculating a pupil diameter under the measurement environment based on the received pupil data, and obtaining an optical characteristic of the eye to be examined based on the calculated pupil diameter and an output signal from the first light receiving part.